S. A. Razgonov, Cand. Sc. (Eng.), Assistant Professor; O. V. Shapovalov, Cand. Sc. (Eng.), Assistant Professor

ABOUT THE UP-DATING OF THE REACTOR OF РОБС-1У TYPE PARAMETERS IN THE PROCESS OF THE ELABORATION OF THE REGULATING TABLE OF THE AUDIO FREQUENCY TRACK CIRCUITS

***Aim of the given study** is the up-dating of the parameters of the reactor of РОБС-1У Type (Single Phase Armoured Dry Type Reactor) during the elaboration of the regulating table of the audio frequency track circuits (ATC). Audio frequency track circuits are supplied from the track circuit transformer of ПОБС -2А (TSPAD) type. Reactor SPADR-1У is used as a restrainer. The analysis of the reasons, influencing the electromagnetic parameters of the reactor of a new model, manufactured in Ukraine is carried out, testing measurements are performed, reactor parameters are recalculated, calculations of the audio frequency track circuits are made, using the updated reactor parameters.*

***Technique.** Measurements of the parameters are performed by means of teslameter. The survey of the market of the cold-rolled transformer steel GO is realized.*

***Results.** Calculations of the values of the input resistances on the terminals of the track line are carried out, complex value of the reactive resistance of the oscillating contour of SPADR-1У and capacitor Cx of the supply circuit of the audio frequency track circuits which were used for the correction of the calculations of the regulating table of ATC of the railway automation systems is recalculated. It is specified that the incorrect operation of the units of the railway automation of signaling, centralization and blocking (SCB) systems may occur as a result of the impact of the traction current on the track circuits, which use SPAGR-1У of the domestic production.*

***Scientific novelty.** Scientific novelty lies in the improvement and correction the coefficients of the formulas for ATC parameters calculation, that enabled to determine more accurately the values in the regulating table of the running line and improve the ATC operation on the used section. Relative errors of the calculations as compared with the seasonal measurements of the parameters, used at the given section did not exceed 3 – 4 % for the currents and voltage.*

***Practical value**. Recommendations, regarding the introduction of the updated coefficients in ATC calculations, where the circuit solutions with the reactors of SPADR-1У type are used, have been developed.*

***Key words**: transport technologies, railway automation, audio frequency track circuits, regulating table, SPADR-1У.*

Survey of the problem. Preliminary survey of the available failures enabled to detect the following characteristic feature that in spite of the reduction of the total amount of failures, the amount of failures that caused the trains delay did not change. The percentage proportion both relatively the devices of the railway automation(RA) that had failures and the reasons of failures did not also change. Such state of things reveals certain problems in the process of replacement and reconstruction of the RA devices within all the sections of JSC “Ukrzaliznytsia”, equipped with audio frequency track circuits (ATC).

We will consider the emergence of the transport events and their consequences. From the point of view of reliability and technical maintenance of RA devices hazardous failures and protective failures are possible. Taking into account the above-mentioned, the analysis of the total array of failures, influencing the operation indices is necessary.

The basis of the analysis comprises the materials of the reports [1] on operation of the automation and telecommunication branch of JSC “Ukrzaliznytsia”. The generalised table 1 is composed on the base of these reports.

Table 1

Statistical data regarding the failures of the railway automation devices

Year	Number of failures	Failures of RA devices, related to service SCB						
		Number	%	Due to operational reasons		Failures, caused trains delay		RA devices
				number	%	number	%	number of train delays
2010	6016	1432	23.8	1262	88.13	324	22.63	905
2011	4837	1515	31.3	1337	88.25	298	19.67	863
2012	4963	1552	31.3	1322	85.18	397	25.58	902
2013	4144	1467	35.4	1197	81.6	409	27.88	884
2014	4890	1196	24.5	968	80.94	302	25.25	720
2015	4832	1299	26.9	1011	77.83	431	33.18	1038
2016	4296	1241	28.9	969	78.08	472	38.03	1123
2017	5310	1330	25.1	1135	85.34	674	50.68	1656
2018	4954	1261	25.5	1065	84.46	664	62.34	1584

Analysis in the generalized table shows that the decrease of the number of failures is observed but the reasons of their emergence and connection of their number with the consequences, regarding the trains delay remain at the same level. Concurrrently, as the total number of the RA devices failures decreases and correspondingly, the number of failures, referred to the service of signaling and communication (SC), the failures percentage increases. Conceivably, this can be explained by different rates of the implementation of organization-technical measure, aimed at the decrease of the number of the RA devices failures in different services, connected with their operation.

Insufficient quantity of the maintenance staff also influences the failures growth. Mistakes, made by the staff are, as a rule, the consequence of the violation of the technology of work performance. That is, non-observence of the normative acts and operation-technical documentation [2, 3]. Percentage of such failures is within the range of 46,3 to 59,5 % (table 2).

Table 2

Reasons of the railway automation devices failures

Reason of the failure		Year								Average value
		2010	2011	2012	2013	2014	2015	2016	2017	
Nonexecution of work	Number	1	0	0	0	1	0	0	2	0.5
	%	0.07	0	0	0	0.08	0	0	0.27	0.04
Violation of the work execution technology	Number	825	901	829	742	584	601	321	365	646
	%	57.6	59.5	53.4	50.6	48.8	46.3	47.7	49.7	52.38
Failure to meet the date of replacement	Number	1	0	1	3	0	1	2	0	1
	%	0.07	0	0.06	0.2	0	0.08	0.3	0	0.08
Errors of BCR	Number	46	49	73	80	57	50	30	20	50.6
	%	3.21	3.2	4.7	5.45	4.77	3.85	4.46	2.72	4.11
Physical ageing of the devices	Number	278	277	285	274	242	263	170	209	249.8
	%	19.4	18.5	18.4	18.7	20.2	20.3	25.3	28.5	20.25
Circuit drawback	Number	6	5	22	16	13	4	2	5	9.125
	%	0.4	0.3	1.42	1.09	1.09	0.31	0.3	0.68	0.74
Undetermined operational reasons	Number	105	105	112	83	71	92	36	62	83.25
	%	7,3	6.93	7.22	5.66	5.94	7.08	5.35	8.45	6.75
Other reasons	Number	170	178	230	269	228	288	112	69	193
	%	11.8	11.8	14.8	18.3	19.1	22,2	16.6	940	15.65

From the range of the official reasons of failure, shown in the Table 2, the most actual are: circuit drawback, undetermined operational reasons and other reasons. Analyzing the failures reasons the conclusion can be made that one of the reasons is based on using the updated version of the device of railway automation SPADR-1У of the domestic production.

Characteristic features of the reactor. Reactors SPADR-1У are intended for the operation in the D. C. double-wound track circuits, as the limiting resistances and serves for the current limitation at the shunt track circuit. Magnetic circuits of the reactors are stocked, pressed, mounted from the plates of electrotechnical steel. Plate packs are tightened by the screws. Magnetic circuits of the reactors have non-magnetic gap of 0.6 mm. Winding of the reactors is layered, made of the copper wire of the wounding round cross-section. Resistance change of the reactors is admissible within the range of ±5%. Cooling of the transformer is natural air-cooling. Reactors are designed for the operation at the ambient temperature from -40 to +65 °C, type of climatic category У, location category 2 according to GOST 15150(State standard). Index of protection according to GOST(State standard) 14254-96 IP20. Manufacturer LLC “Ukrzalizprom”, according to TC(Technical conditions) Y 31-1.33413181-001:2008. Technical characteristics are shown in table 3.

Table 3

Technical characteristics of SPADR-1У

Form factor	Total resistance of the resistance box, 0hm, at current frequency, Hz		Rated voltage, V	Rated current, A, at current frequency, Hz		Copper losses, W	Mass, kg
	50	25		50	25		
SPADR-1У ASD 419.00.00.00	0.74	–	10	13.5	–	11	2.6 – 3.2
SPADR-1У (sealed) ASD 419.00.00.00-01							

Producers of the transformer steel. In India and China the economic growth is provided by large state investments in the development of the infrastructure, in particular – energy sector. However the demand for electrotechnical steel in these countries grows rapidly. Three categories of steel are used: grain-oriented silicon electrosteel (GO), random-oriented silicon electrosteel (NGO) and steel from non-oriented metal without silicon (NO). In recent years the NGO market in the sphere of household appliances and automobile industry is rapidly developing. The demand for steel, made of GO material, is the highest in the developing countries, expanding or upgrading their power generating branch of industry. This category of steel is used for the manufacturing of the cores of the static electric devices, namely, various types of transformers. That is why, this material is often called “transformer steel”. Sheet material GO has the property of anisotropy of the electromagnetic indices: magnetic domains are directed in the direction of the rolling. This material is characterized by large crystals. That is why, its magnetic permeability is greater, but it has less coercitive force, as compared with the materials with small crystals. The size of grains depends on mechanical or thermal treatment.

Nowadays, in the production of the transformer cores both cold-rolled and hot-rolled steel GO is used. However, in the transformers with the cores, made of hot-rolled material large energy losses are observed. That is why, in Ukraine cheap cold-rolled steel GO is used for the needs of power generation branch [4].

Characteristic features of reactors manufacture. Ukrainian producers of RA devices in general and, in particular SPADR-1У buy in China pressed cores, made of cold-rolled steel of GO type. Electric characteristics of SPADR-1У reactor practically do not differ from the electric characteristics of SPADR reactor, which was manufactured for RA devices in the period of the USSR. But magnetic characteristics of the steel of GO type differ from the characteristics of the steel, used before. For the decrease of the product price the copper wire was replaced in the winding of the reactor by the modern copper-plated wire, manufactured in China. Copper-plated wire has metal iron core, covered with the layer of copper of several microns. It is obvious, that such wire has different magnetic characteristics than the copper wire, made of technical copper. The replacement of the constituent elements greatly influenced operation parameters of SPADR-1У reactor, having negative impact on the functioning of ATC.

Sphere of SPADR application in ATC. TRC is supplied from the track circuit transformer TSPAD-2A. Reactor SPADR-1У is used as a limiter. Single-phase, armored-type dry reactors are designed for the operation in the double wound A. C. track circuits as the bias resistors for current limitation at the shunt of the track circuits. Capacitors of К73-П-2-400V type (total capacitance 60/50/30/25/20 mF, correspondingly) installed at the supplying and relay terminals are intended for reducing the consumed power and protection against the impact of other signal frequences.

Reactor SPADR-1У and capacitor, connected in series, form the oscillating circuit. At the resonance of the oscillating circuit theoretically zero reactive resistance will be obtained at the corresponding audio frequency of 420 – 780 Hz. However, the values of the reactive resistances of SPADR-1У and capacitors do not correspond to the resonance values. It is established that SPADR-1V and capacitors have 10 % of deviation in the constructive values. That is why, at each of the audio frequences different complex values of the resistances are obtained, this influences the quality of ATC operation. It became one of the reasons for measuring the parameters of the reactors, manufactured by the domestic industry.

The values of the input resistances at the terminals of the track line used for the calculation of the regulating table, are calculated by the formula [5]:

$$Z_{inp} = R_L + R_p + |\dot{x}| + R_c,$$

where: R_L – is the loading resistance of the relay or supply terminal; R_p – is protective resistance of the circuits, 0.3 Ohm; $|\dot{x}| = |x_L + x_c|$ is complex value of the reactive resistance of the oscillating circuit of SPADR-1У and capacitor; R_c – is a real resistance of the cable line, that occurs at the specific resistance of 59 Ohm/km).

For each audio frequency the capacitor of the corresponding value is used from the list of industrial capacitors. Correspondance of the audio frequency and capacitance of the capacitor are presented in the Table 4.

Table 4

Correspondances of the audio frequences values and capacitors capacitance

Carrying audio frequency, Hz	420	480	580	720	780
Capacitor capacitance, mF	60	50	30	25	20

Pattern of SPADR measurements. According to the request of Dnipro division of the branch of “Design-Surveying Institute of Railroad Transport” of PJSC “Ukrzaliznytsia” SPADR-1У measurements were conducted according to the pattern, presented in Fig. 1.

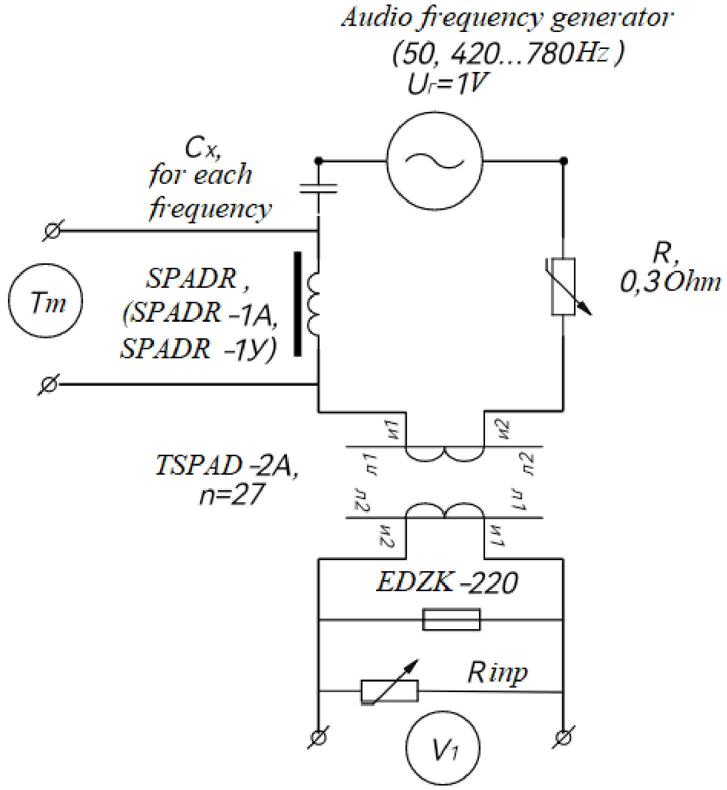

Fig.1. Pattern of measurements

Explications to the pattern. Measurements are conducted at the voltage of audio frequences generator 1 V at the following frequences: 420 Hz, 480 Hz, 580 Hz, 720 Hz, 780 Hz. For each frequency the capacitor Cx of К73-П-2-400V type of the corresponding capacitance was installed: 60/50/30/25/20 mF. Tm – tesla meter for measuring the magnetic induction of SPADR-1У. TSPAD-2A – is track transformer with the transformation ratio n=27. ВОЦН (EDZK)-220 – automatic equaliser; V_1 – voltmeter, SPADR (SPADR-1A, SPADR-1У) – reactors, manufactured in different periods of time: SPADR –in 1950s; SPADR-1A in 2010s; SPADR-1У in 2020s. Rinp –is equivalent value of the input resistances on the terminals of ATC.

The results obtained. According to the results of measurements the following results are obtained: the values of the input resistances on the terminals of TRC are recalculated on a secific section of the running line of Cisdnieper Railway (Table 5); values of the complete complex resistance Z of the oscillating circuit of SPADR-1У – Cx for corresponding audio frequences are corrected (Table. 6).

Table 5

Calculated values of the input resistances on the terminals of ATC

№	Carrying audio frequency, Hz	Complex value of Zinp, Ohm			
		relay terminal (RT)		supply terminal (ST)	
		Value	argument (angle φ), deg	Value	argument (angle φ), deg
1	420	0.6	+6	0.92	+0
2	480	0.85	+45	1.1	+38
3	580	0.75	-56	1,1	-30
4	720	2.1	+73	2.2	+75
5	780	1.7	+69	1.9	+60

Table 6

Corrected values

№	Frequency, Hz	Complex impedance Z, Ohm
1	25	$0.37\ e^{j\text{-}88°}$
2	50	$0.74\ e^{j\text{-}88°}$
3	420	$6.216\ e^{j\text{-}89°}$
4	480	$7.104\ e^{j\text{-}89°}$
5	580	$8.584\ e^{j\text{-}89°}$
6	720	$10.656\ e^{j\text{-}89°}$
7	780	$11.544\ e^{j\text{-}89°}$

Obtained recalculated values enabled to correct the coefficients of the formulas for ATC parameters calculation, that allowed to determine more accurately the values in the regulating table of the running line and improve the operation of ATC on the section already used. Relative errors of the calculations as compared with the seasonal measurements of the parameters, applied on the section already used did not exceed for currents and voltages 3 – 4 %. Recommendations have been elaborated regarding the implementation of the corrected coefficients in ATC calculations where circuit engineering solutions with the reactors of SPADR-1У type are used.

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Razgonov Serghiy – Cand. Sc. (Eng.), Assistant Professor, Department of Transport Technologies and International Logistics.

Shapovalov Oleksiy – Cand. Sc. (Eng.), Assistant Professor, Department of Transport Technologies and International Logistics.

Dnipro University of Customs and Finance.